# WEST Search History

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DATE: Thursday, June 09, 2005

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L8: Entry 1 of 19 File: USPT Feb 22, 2005

DOCUMENT-IDENTIFIER: US 6859496 B1
TITLE: Adaptively encoding multiple streams of video data in parallel for multiplexing onto a constant bit rate channel

Application Filing Date (1):
19990105

Brief Summary Text (9):
A need thus exists in the art for a multi-program compression technique which dynamically distributes available bandwidth among the programs in order to optimize overall video quality of the system. The present invention provides such a technique by employing a joint rate control strategy which guides the individual encoders dynamically during the encoding process.

Brief Summary Text (17):
To restate, presented herein is a system solution for statistical multiplexing (stat-mux) which encodes several video programs in parallel using, for example, MPEG-2 compatible video encoders. A joint rate control strategy is presented which dynamically allocates bit rates among the encoders. The bit rate of each encoder is determined based, for example, on relative complexities of the programs and scene changes occurring within the programs being encoded. Relative complexity is evaluated using one or both of "image statistics" obtained prior to encoding a particular picture and "coding statistics" obtained as a result of coding a particular picture. Thus, image statistics characterize a current picture yet to be encoded, while coding statistics provide information on the previous picture encoded.

Drawing Description Text (7):
FIG. 5 is a flowchart of one embodiment of a stat-mux rate control processing in accordance with the principles of the present invention.

Detailed Description Text (2):
As briefly noted above, this invention relates to a statistical multiplexing control strategy for encoding multiple streams (e.g., channels) of video programs in parallel using multiple video encoders. An external joint rate control strategy is employed which dynamically allocates bit rates among the encoders (which may comprise MPEG compliant encoders and encoding processes such as described in the above-incorporated MPEG-2 International Standard). The bit rate of each encoder is determined based on relative complexities of the programs and adjustments are made, e.g., at scene changes and GOP boundaries inside the programs. The proposed technique determines relative complexities using either or both of picture statistics and coding statistics. As used herein, "picture statistics" or "image statistics" refers to information gathered on at least one characteristic of a picture by looking ahead and evaluating pictures still to be encoded. Thus, this aspect of the technique is referred to as a look-ahead approach. The "coding statistics" comprise those statistics discussed in the above-incorporated parent application which are generated commensurate with encoding of a picture and fed back for use in encoding a next picture. Thus, coding statistics provide a historical indication of picture complexity. As described further herein, the

present invention selectively employs either picture statistics alone for example, at the start of encoding or whenever there is scene change in one of the, streams of video data, or a combination of picture statistics and coding statistics in a predefined relationship. FIGS. 1 & 2 depict the operation of a single video encoder to be employed in a system in accordance with this invention.

Detailed Description Text (8):
The operational functions of an MPEG-2 encoder are discussed in greater detail in commonly assigned, co-pending U.S. patent application Ser. No. 08/831,157, by Carr et al., filed Apr. 1, 1997, entitled "Control Scheme For Shared-Use Dual-Port Predicted Error Array," which is hereby incorporated herein by reference in its entirety. The fundamentals of constant bit rate (CBR) and variable bit rate (VBR) encoding schemes are described with reference to groups of pictures (GOPs) or frames in detail in commonly assigned, co-pending U.S. patent application Ser. No. 09/044,642, by N. Mohsenian, filed Mar. 19, 1998, entitled "Real-Time Single Pass Variable Bit Rate Control Strategy And Encoder," which is hereby incorporated herein by reference in its entirety. Adaptive encoding of a sequence of frames using image statistics such as described herein below, is described in additional detail in commonly assigned, co-pending U.S. patent application Ser. No. 09/046,118, by Boice et al., filed Mar. 20, 1998, entitled "Adaptive Encoding Of A Sequence Of Still Frames Or Partially Still Frames Within Motion Video," which is also hereby incorporated herein by reference in its entirety.

Detailed Description Text (9):
With the above information as background, statistical multiplexing and rate control strategy in accordance with the principles of the present invention is described below with reference to FIGS. 3-5.

Detailed Description Text (10):
In typical statistical multiplexing systems, several video bitstreams are multiplexed onto one single constant bit rate channel. Unfortunately, encoding of each program at a predefined constant bit rate can lead to picture quality degradation due to changes in scene content over time. Thus, the underlying objective of multi-program compression in accordance with the present invention is to dynamically distribute the available bandwidth among the programs in order to maximize the overall video quality of the system. This corresponds to equalizing the picture quality of all programs using a joint rate control algorithm that guides the individual coders. The invention allocates bit rates among the encoders according to the relative scene content of the video sources, while still meeting the requirement of a fixed channel bit rate.

Detailed Description Text (11):
More particularly, a system solution for statistical multiplexing is presented for encoding several video programs in parallel using MPEG-2 compatible video encoders. An external joint rate control algorithm that dynamically allocates bit rates among the encoders is described. The bit rate of each encoder is determined based on relative complexities of the programs and scene changes inside the programs. A system/method in accordance with the present invention does not require the same GOP structure or GOP length in each encoder. Each encoder changes its bit rate at GOP boundaries according to the joint rate control, while it operates at constant bit rate inside the GOPs. Overall, this strategy results in a piece-wise constant, variable bit rate compression. Experimental results show that a multi-program video compression system in accordance with the present invention results in good picture quality, with fast response time to a scene change. Furthermore, commercially available MPEG-2 encoder chips can be used successfully in this system.

Detailed Description Text (12):
Basically, two-different approaches are employed for joint rate control, a feedback approach and a look-ahead approach. In the feedback approach, statistics are generated by the encoders as a by-product of the encoding process. These coding

statistics are then used to in part control the bit allocation for subsequent pictures. In the look-ahead approach, statistics are computed by a preprocessor prior to encoding, with these image statistics then being used to adjust the bit rates before encoding the pictures as described herein. With either approach, finding the optimum statistics which describe the complexity of a program can be challenging. In the feedback approach, the statistics are mostly limited to coding related quantities. The look-ahead approach can have more freedom but the price is extra computational complexity and/or additional devices.

Detailed Description Text (13):
Using either or both approaches, a joint rate control algorithm would calculate the bit rate for each picture and carry out the entire rate control for each of the individual encoders. This results in variable bit rate encoding. Conventionally, such a rate control algorithm would require mostly identical GOP structure in each encoder, which is, however, far from reality. Encoders can and do operate in different GOP lengths and structures.

Detailed Description Text (14):
Pursuant to this invention, a solution is disclosed for statistical multiplexing by dynamically allocating bit rates for the encoders using both a look-ahead and a feedback approach. The rate control strategy distributes the channel bit rate among the encoders based on the relative complexity of the programs. The complexity of the programs is determined using picture statistics generated by pre-processors and coding statistics that are generated by the encoders, along with the compressed bitstreams. Alternatively, the encoders could be modified to generate both the picture statistics and the coding statistics by incorporating the preprocessing function therein as will be apparent to one skilled in the art based upon the discussion provided herein.

Detailed Description Text (15):
Instead of calculating the target bit rate for each picture by the joint rate control algorithm, the bit rates are changed at GOP boundaries, or if a scene change occurs. This strategy allows the encoders to operate at constant bit rate inside the GOPs, resulting in a piece-wise constant, but variable bit rate compression. The encoders do not have to have identical GOP structures, that is, GOP boundaries can occur in each encoder at different times. Due to the different GOP structures of the encoders, a channel buffer and a corresponding buffer control feedback loop are incorporated into a system in accordance with the present invention. At scene changes, quick reactions are assured by changing GOP structures dynamically and allowing adequate bit rate changes. The present system/method may be implemented using, for example, International Business Machines' single chip MPEG-2 video encoders, part number IBM39 MPEGS422 PBA 17C.

Detailed Description Text (16):
Section 1 below describes a multi-program video compression system in accordance with the present invention. The joint rate control strategy of this invention is then presented in detail in Section 2. The strategy for joint rate control in the case of scene change is described in Section 3. Determination of the minimum size of the channel buffer and the corresponding channel buffer control is given in Section 4. A possible use of commercially available single chip MPEG-2 encoders in the present system is highlighted in Section 5. A process overview is then given in Section 6.

Detailed Description Text (19):
System 200 also includes several MPEG-2 video encoders 210, individual buffers 220 connected to the encoders 210, a joint rate controller 230, a multiplexer 240, and a channel buffer 250. Encoders 210 each receive a respective delayed program (Delayed Source 1, Delayed Source 2, Delayed Source 3, . . . Delayed Source n) for encoding. The delay is sufficient to allow preprocessors 205 to perform the analysis described hereinbelow. Note that in an alternate embodiments, the picture

statistics generating function could be integrated into the MPEG-2 encoders 210 if desired. Each encoder 210 also generates coding statistics about the picture that has just been encoded. These coding statistics, along with the picture statistics, are input parameters to the joint rate control algorithm 230, which calculates the bit rate of each individual encoder dynamically as described herein below.

Detailed Description Text (20):
In the proposed system 200 the bit rate of each encoder 210 is determined based on the relative complexities of the programs (Source 1, Source 2 . . . Source n), and upon occurrence of a scene change inside the corresponding program. The encoders preferably produce bitstreams compatible with the MPEG-2 standard. The scene change detection can be conventionally done either inside or outside of the encoders 210. Each encoder changes its bit rate at GOP boundaries or at scene changes according to the joint rate control 230. This allows the encoders to operate at a constant bit rate (CBR) inside the GOPs using the CBR video buffer verifier model according to the MPEG-2 standard. Overall, this strategy results in a piece-wise constant, but still variable bit rate compression.

Detailed Description Text (21):
The encoding of video sources is not restricted to having identical GOP structures or GOP lengths in each encoder. Since GOP boundaries can occur in each encoder at different times and bit rate changes take effect only at GOP boundaries, channel buffer 250 is employed to compensate possible overflow or underflow of the channel rate. A channel buffer control feedback 255 is also incorporated into the joint rate control algorithm 230 in order to prevent channel buffer 250 overflow or underflow.

Detailed Description Text (22):
In the following description of the present invention, the joint rate control strategy, determination of the minimum size of the channel buffer, and the corresponding channel buffer control are discussed in more detail.

Detailed Description Text (23):
2. Joint Rate Control

Detailed Description Text (24):
The joint rate control strategy presented herein is based on a combined look-ahead and feedback concept wherein statistics are produced prior to encoding (herein "picture statistics"), as well as during encoding (herein "coding statistics"). These statistics are fed into the joint rate controller 230, together with the information on channel buffer 250 fullness. The rate control strategy, which guides the individual encoders during the encoding process, dynamically distributes the available bandwidth among the programs according to their relative complexities. The relative complexities of the programs are determined herein based on the picture statistics and the coding statistics.

Detailed Description Text (25):
Information related to the picture scene content of a frame can be estimated, for example, as the average activity of a frame. It is calculated as the average macroblock activity over an entire frame. Calculating the average activity for several frames ahead of the picture being encoded results in a look-ahead in the joint rate control algorithm. As noted, the average activity can be calculated either inside of the encoders or by preprocessing units (e.g., the preprocessors of FIG. 3). The coding complexity of a program is estimated using coding statistics which are generated by each encoder as a by-product of the encoding process. For example, the coding complexity can be determined based on the bits used for encoding a picture and the average quantization parameter used for, the picture.

Detailed Description Text (26):
Using the picture and coding complexities, the bit rate of an encoder is assumed to

be proportional to the weighted sum of two ratios: One is the ratio between the coding complexity of that program and the sum of the coding complexities of all programs. The other ratio is calculated between the average activity of that program using several frame look-aheads and sum of the average activity of all programs. If scene change occurs or at start of encoding, the complexity of a program is preferably solely determined based on the average frame activity (i.e., picture statistics). If no scene change occurs, the picture and coding statistics ratios are used in a predefined relation, for example, in equal parts. One embodiment of a joint rate control strategy in accordance with this invention is presented further below.

Detailed Description Text (30):
Look-ahead of several frames is incorporated into the joint rate control algorithm by using Eqs. (1) and (2). For example, in our experiments we have calculated the average activity for four frames ahead of the picture being encoded.

Detailed Description Text (37):
3. Joint Rate Control at Scene Changes

Detailed Description Text (38):
Previously it was stated that the encoders are running in CBR mode inside the GOPs and that each encoder uses a CBR video buffer verifier model. No buffer under- or overflow is allowed. For example, a goal in the CBR rate control algorithm may be to ensure that buffer fullness at the end of the GOP will be the same as the initial buffer fullness (e.g. 80% of the buffer size). This may not always be the case, however, due to mismatch of the target bit budget and of the actual bits used per picture. Because of the over- or underproduction of bits in a GOP, the buffer fullness will be under or over the initial level, respectively. A considerably large buffer fullness error can accumulate. This error is carried over and tried to be compensated for in the next GOP. This rate control works fine if little or no bit rate changes take place at GOP boundaries. If bit rate changes are abrupt, however, such as at scene changes, a buffer fullness error (BFE) strategy in accordance with the present invention is applied to further improve the picture quality.

Detailed Description Text (40):
where R.sub.i is the calculated bit rate for program i according to Equation (4), E is the buffer fullness error bits, N.sub.i is the number of pictures in a GOP and f.sub.i is the frame rate for program i. The bit rate of the program will be increased if the buffer fullness error is positive (the buffer fullness in the beginning of the GOP was less than the initial), or it will be decreased if E is negative. For rate control inside the GOP, the initial buffer fullness is considered as the buffer fullness at the end of the previous GOP instead of using, for e.g., 80% of the buffer size. The BFE strategy results in enhanced picture quality after scene changes.

Detailed Description Text (68):
All MPEG-2 encoders used in a multi-program video compression system in accordance with the principles of the present invention must be capable of providing at least the necessary coding statistics required by the joint rate control algorithm discussed above. Encoders must also have the ability to change bit rates at GOP boundaries. To further exploit the advantages of this invention, in the event of scene changes encoders must be able to change GOP structure dynamically, provide quantities for calculating the buffer fullness error and carry out scene change detection and reaction either internally or externally.

Detailed Description Text (72):
To again summarize, in accordance with this invention, a joint rate control strategy is presented which dynamically allocates bit rates among multiple encoders for encoding video streams in parallel for multiplexing onto a common channel. The

channel bit rate is distributed among the encoders based on relative complexity of the programs and scene changes occurring with the programs. The complexity of the programs is determined based on look-ahead picture statistics, and feedback coding statistics, as well as scene change detection. Picture statistics can be generated, for example, by preprocessors, and the coding statistics and scene change detection signals are generated by the encoders along with the compressed bitstreams. Instead of calculating the target bit rate for each picture, the bit rates are changed at GOP boundaries or if a scene change occurs. This allows the encoders to operate in constant bit rate (CBR) inside the GOPs.

Other Reference Publication (2):
Gertjan Keesman, "Multi-Program Video Compression Using Joint Bit-Rate Control", Philips Journal of Research, vol. 50, No. 1/2, 1996, pp. 21-45.

Other Reference Publication (4):
Limin Wang and Andre Vincent, "Joint Rate Control for Multi-Program Video Coding", IEEE Transactions on Consumer Electronics, vol., 42, No. 3, Aug. 1996, pp. 300-305.

Other Reference Publication (5):
Ajanta Guha and Daniel J. Reininger, "Multichannel Joint Rate Control of VBR MPEG Encoded Video For DBS Applications", IEEE Transactions on Consumer Electronics, vol. 40, No. 3, Aug. 1994, pp. 616-623.

CLAIMS:

9. The method of claim 1, wherein said adaptively encoding comprises employing a rate control algorithm to control an encode bit rate of each stream of said multiple streams of video frames, and wherein said method comprises providing said picture statistics and said coding statistics to said rate control algorithm, said picture statistics and said coding statistics being representative of said relative complexity of the video frames comprising said multiple streams of video frames to be encoded.

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L18: Entry 1 of 1 File: USPT Sep 7, 2004

DOCUMENT-IDENTIFIER: US 6788740 B1
TITLE: System and method for encoding and decoding enhancement layer data using base layer quantization data

Application Filing Date (1):
19991001

Detailed Description Text (13):
Quantization circuit 216 provides inputs for the base layer feedback path, entropy coder 218, and enhancement layer encoding unit. Depending upon the application and video quality, quantization circuit 216 may also use a weighting factor to adjust quantization of the transform output.

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L5: Entry 1 of 19 File: USPT Feb 22, 2005

DOCUMENT-IDENTIFIER: US 6859496 B1
TITLE: Adaptively encoding multiple streams of video data in parallel for multiplexing onto a constant bit rate channel

Application Filing Date (1):
19990105

Detailed Description Text (10):
In typical statistical multiplexing systems, several video bitstreams are multiplexed onto one single constant bit rate channel. Unfortunately, encoding of each program at a predefined constant bit rate can lead to picture quality degradation due to changes in scene content over time. Thus, the underlying objective of multi-program compression in accordance with the present invention is to dynamically distribute the available bandwidth among the programs in order to maximize the overall video quality of the system. This corresponds to equalizing the picture quality of all programs using a joint rate control algorithm that guides the individual coders. The invention allocates bit rates among the encoders according to the relative scene content of the video sources, while still meeting the requirement of a fixed channel bit rate.

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L5: Entry 2 of 19 File: USPT May 7, 2002

DOCUMENT-IDENTIFIER: US 6385241 B1
TITLE: Method and apparatus for video rate control using a radial basis function rate estimator

Application Filing Date (1):
19980204

Brief Summary Text (10):
To solve the above problems, it is an object of the present invention to provide a MPEG video rate control method and apparatus therefor using predicting the future occupancy, i.e. by estimating the video rate for the next picture in order to smooth the video rate without introducing noticeable quality degradation.

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L5: Entry 3 of 19 File: USPT Aug 21, 2001

DOCUMENT-IDENTIFIER: US 6278735 B1
** See image for Certificate of Correction **
TITLE: Real-time single pass variable bit rate control strategy and encoder

Application Filing Date (1):
19980319

Detailed Description Text (40):
The efficiency of a single pass VBR encoder is assessed by how fast its rate control technique can learn and adjust itself to the softness or hardness of the video stream. For regions where image discontinuity or special effects occur, degradations in picture quality should be minimized. Since, for single pass encoding, image statistics are limited by the previously analyzed and encoded pictures, the learning rate of the rate control technique should be adequate enough to predict the content of the future video intervals, yet not be too aggressive to result in algorithmic instabilities. One way to solve the twofold problem is to adjust the quality of the encoded stream for every time interval (i.e., every GOP) and let the rate control technique learn the local content of each picture within that time interval.

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L5: Entry 4 of 19 File: USPT Sep 12, 2000

DOCUMENT-IDENTIFIER: US 6118817 A

**** See image for Certificate of Correction ****

TITLE: Digital video signal encoder and encoding method having adjustable quantization

Application Filing Date (1):
19970314

Detailed Description Text (8):
In test step 306, primary open loop rate control 202 (FIG. 2) determines whether the current frame is larger than the target size. If the current frame is larger than the target size, processing transfers from test step 306 (FIG. 3) to step 308. In step 308, primary open loop rate control 202 (FIG. 2) increases Q 114 to thereby cause subsequent frames to be encoded at with an increased degree of compression and a commensurate degradation of motion video image quality. By increasing the degree of compression of the motion video signal, exceeding the available bandwidth is avoided.

L5: Entry 14 of 19 File: USPT Apr 1, 1997

DOCUMENT-IDENTIFIER: US 5617150 A
TITLE: Video bit rate control method

Abstract Text (1):
A video bit rate control method. SUBGOPs are defined as sets of two to four frames in a GOP. For example, if the GOP comprises IBBPBBPBBPBB frames, each of the SUBGOPs is defined as a set of the IBBP or BBP frames. Before bit assignment is performed with respect to frames to be coded, it is checked whether a scene change is present with respect to frames in successive ones of the SUBGOPs. If it is checked that the scene change is not present, a bit rate is controlled in a conventional manner. In the case where the scene change is present, a smaller bits than that in the conventional manner is assigned to frames with no scene change and a relatively large bit amount is assigned to a frame with the scene change. Therefore, according to the present invention, the video bit rate control method has the effect of preventing a degradation in a picture quality due to the scene change.

Application Filing Date (1):
19950619

Brief Summary Text (6):
In order to maintain the coded output bit rate constant, bits necessary to the coding must be controlled properly every frame. In this case, a degradation in the picture quality may become an issue. As a result, there has been proposed an effective video bit rate control method which is capable of avoiding an abrupt degradation in the picture quality and maintaining the coded output bit rate constant within the transmission channel band.

Brief Summary Text (11):
By the way, in the above-mentioned conventional video bit rate control method, in the case where a sudden scene change occurs in the middle of coding the frames in the GOP, much bits are required to maintain the picture quality constant. In this case, the remaining bit amount is used to code a scene change frame and the subsequent frames because the constant bit amount was used for the frames previously coded. As a result, there is caused a degradation in the picture quality in any form. This degradation in the picture quality has a bad effect on a high definition television application.

Brief Summary Text (13):
Therefore, the present invention has been made in view of the above problem, and it is an object of the present invention to provide a video bit rate control method in which SUBGOPs are defined as sets of two to four frames in a GOP (for example, if the GOP comprises IBBPBBPBBPBB frames, each SUBGOP is defined as a set of the IBBP or BBP frames), it is checked, before bit assignment is performed with respect to frames to be coded, whether a scene change is present with respect to frames in successive ones of the SUBGOPs, a bit rate is controlled in a conventional manner if the scene change is not present, and, if the scene change is present, smaller bits than that in the conventional manner are assigned to frames with no scene change and a relatively large bits are assigned to a frame with the scene change, so that a degradation in a picture quality due to the scene change can be

prevented.

Detailed Description Text (16):
As apparent from the above description, according to the present invention, the video bit rate control method can control the video bit rate effectively even upon the occurrence of the sudden scene change. Therefore, the video bit rate control method of the present invention can effectively be applied to a broadcasting field in which a degradation in a picture quality due to the scene change becomes an issue, or a digital storage medium edit field in which a high efficient compression is required. Further, the video bit rate control method of the present invention may be applied to a video communication video codec such as a video phone, a storage medium video codec and a digital broadcasting video codec utilizing a digital video compression technique.

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L6: Entry 8 of 16 File: USPT Jul 21, 1992

DOCUMENT-IDENTIFIER: US 5132792 A
TITLE: Video signal transmitting system

Application Filing Date (1):
19901012

Detailed Description Text (67):
Thus, in this embodiment, a component which is hard for a viewer to recognize is accorded an equivalently enlarged quantization interval by weighting processing coefficients of which data are output from the discrete cosine transformation circuit 12 according to error data ER output from the motion vector detecting circuit 6, and thereby a degradation of picture quality is effectively avoided and video signals are efficiently transmitted.

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L6: Entry 15 of 16 File: EPAB Jan 20, 1999

DOCUMENT-IDENTIFIER: EP 892564 A2
TITLE: Attentional maps in objective measurement of video quality degradation

Abstract Text (1):
CHG DATE=19990905 STATUS=O> Attentional maps that reflect the subjective view of an observer to the effects of degradation in a video image are used in the objective measurement of video quality degradation. The observer assists in generating an attentional map for each image of a test image sequence, which provides different thresholds or weighting factors for different areas of each image. A video image sequence from a system under test is compared with the test image sequence, and the error results are displayed as a function of the corresponding attentional maps.

Application Date (1):
19980717

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L6: Entry 4 of 16 File: USPT Aug 17, 1999

DOCUMENT-IDENTIFIER: US 5940124 A
TITLE: Attentional maps in objective measurement of video quality degradation

Abstract Text (1):
Attentional maps that reflect the subjective view of an observer to the effects of degradation in a video image are used in the objective measurement of video quality degradation. The observer assists in generating an attentional map for each image of a test image sequence, which provides different thresholds or weighting factors for different areas of each image. A video image sequence from a system under test is compared with the test image sequence, and the error results are displayed as a function of the corresponding attentional maps.

Application Filing Date (1):
19970718

Brief Summary Text (11):
Accordingly the present invention provides attentional maps in the objective measurement of video quality degradation. The attentional maps provided weighting values according to the amount of subjective influence each portion of each frame of a test image sequence has on an observer. The test image sequence is then transmitted through a system under test to generate a degraded test image sequence. The degraded test image sequence is compared to the test image sequence according to a selected measurement algorithm with the results being weighted by the corresponding attentional maps. The measurement outputs are provided on an appropriate measurement display.

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